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ABSTRACT

This third in a series of seven modules for a course titled Nondestructive Examination (NDE) Techniques I describes the principles and practices associated with hydrostatic testing. The module follows a typical format that includes the following sections: (1) introduction, (2) module prerequisites, (3) objectives, (4) notes to instructor/student, (5) subject matter, (6) materials needed, (7) procedures, (8) data table, (9) reference materials, (10) test. (The course is one of fifteen technical courses for the second year of a two-year postsecondary curriculum in Nuclear Quality Assurance/Quality Control Technology.) (LRA)

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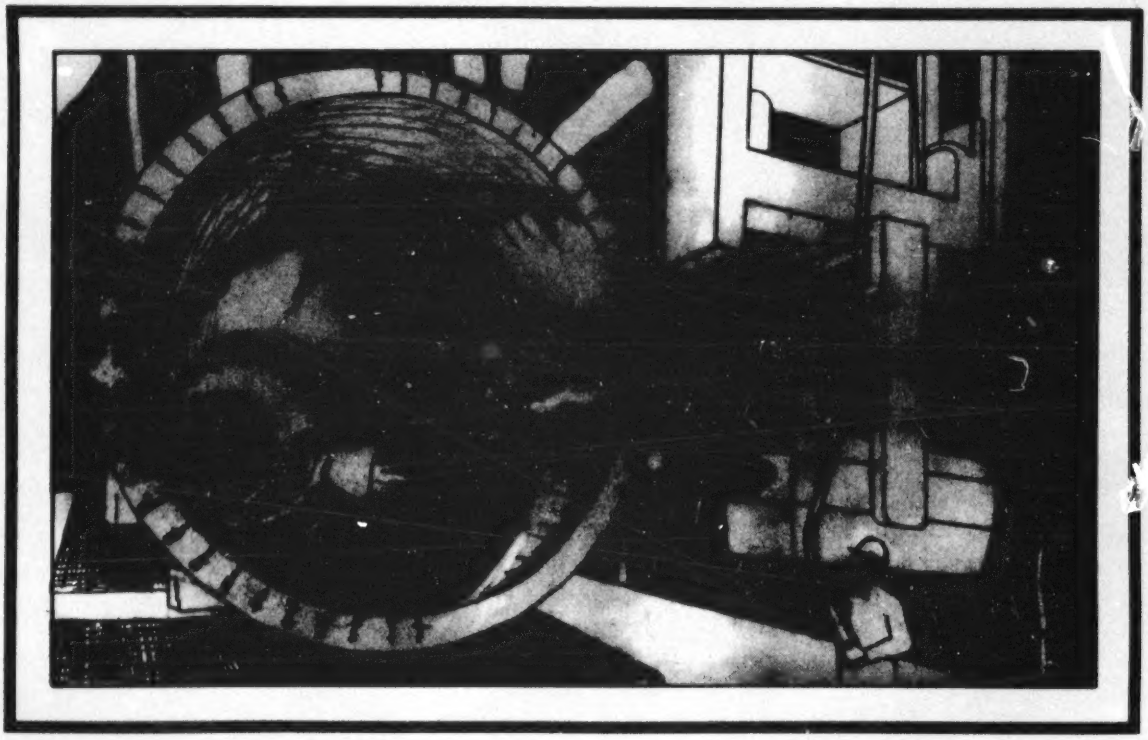
NUCLEAR TECHNOLOGY

COURSE 26 NONDESTRUCTIVE EXAMINATION (NDE) TECHNIQUES I

MODULE 26-3 Hydrostatic Tests



CE 024 248

GENERAL PHYSICS CORPORATION
Columbia , Maryland

COURSE MODULES

COURSE 26 NONDESTRUCTIVE EXAMINATION (NDE) TECHNIQUES I

Module 26-1 Visual Tests
Module 26-2 Leak Tests
Module 26-3 Hydrostatic Tests
Module 26-4 Liquid Penetrant Tests
Module 26-5 Fundamentals of Radiography
Module 26-6 Radiography Inspection
Moduel 26-7 Radiographic Specifications and Code Requirements

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This module was prepared for General Physics Corporation by Rick Pelton and John Espy, General Physics Corporation

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1979

INTRODUCTION

The Nuclear QA/QC technician can have responsibilities with respect to hydrostatic testing in planning for or monitoring the tests. Specific tasks include (1) initial drafting of test procedures, (2) review of test procedures for compliance with codes, specifications and standards, and (3) monitoring the conduct of hydrostatic testing.

Hydrostatic testing provides a means of determining that pressure retaining systems do not leak excessively at design pressure. The test uses the characteristics of water at rest, i.e., in equilibrium. It is relatively simple and inexpensive although safety precautions apply.

Both individual components and complete systems are hydrostatically tested. Individual components are normally tested by the manufacturer of the component. Systems are tested at the close of the construction phase of the power plant and prior to operating the plant. Also, systems and components are tested periodically throughout their service life.

This module describes the principles and practices associated with any hydrostatic test. However, because system hydrostatic testing is more complex, primary emphasis is given to testing at the power plant site.

MODULE PREREQUISITES

Prior training or experience in leak testing is required for this module. Completion of Nuclear Technology, Module 26-2, Leak Tests, satisfies this prerequisite.

OBJECTIVES

1. Describe fundamental principles associated with hydrostatic testing including the effects of compressibility, Pascal's law, gases, and temperature.
2. Draw a simplified diagram of a typical hydrostatic testing system, label test equipment and describe the function of each type of equipment.
3. Describe the role or purpose of the prerequisite when given any of nine prerequisites for system hydrostatic testing.
4. Describe the role of these elements of the written hydrostatic test procedure: title, applicability, prerequisites, main body, acceptance criteria and check off lists.
5. Describe techniques for ensuring any of the following: system boundary isolation, complete venting, protection from altering system line up during hydrostatic testing, and removal of temporary supports and connections.
6. Name three attributes which are inspected during hydrostatic testing and discuss the purpose of each.
7. Discuss a pneumatic pressure test with respect to (a) when it is used, (b) types of gases used, (c) application of pressure and (d) methods of inspecting for leaks.
8. State the purpose of inservice pressure tests and relate them to initial hydrostatic tests with regard to time at pressure and visual inspection techniques.

This module describes three procedures which reinforce the concepts presented. At least one procedure should be accomplished by each student/trainee. Advance preparation will be necessary for the activity selected. In this regard each procedure lists recommended materials and gives other suggestions for necessary preparations.

HYDROSTATIC TESTING FUNDAMENTALS

Fundamental Principle

Hydrostatic testing uses the fundamental principle that liquids are essentially incompressible. When a closed system is completely filled with liquid, further addition of liquid greatly increases the internal pressure. Conversely, loss of liquid from a pressurized liquid system results in marked loss of pressure.

Units of Pressure

Pressure is force per unit area. Therefore, the units used for force and area establish the units for pressure. The English system uses pounds force (lbf) and square feet (ft^2) or square inches (in^2). The International system mostly uses newtons (N) and square meters (m^2) although dynes (dyn) and square centimeters (cm^2) are sometimes used. These units are illustrated as follows:

$$P = F/A = lbf/ft^2 \text{ or } lbf/in^2 \text{ (English)} \qquad \text{Equation 26-3-1}$$

$$= N/m^2 \text{ (International)}$$

$$= dyn/cm^2 \text{ (International)}$$

where:

P = pressure
F = force
A = area

Pascal's Law

Because liquids are incompressible, a force exerted on a confined fluid creates a pressure which is transmitted

throughout the fluid. This fact was first deduced by Pascal in 1653 and is commonly known as Pascal's law which states:

> Pressure applied to a confined liquid (or gas) is transmitted undiminished throughout the confining vessel or system.

Effects of Gas

Unlike liquids, gases are compressible. A relatively large change in volume of a confined gas is necessary for a substantial pressure change. This relationship is expressed by the equation for the ideal gas law:

$$\frac{P_1V_1}{T_1} = \frac{P_2V_2}{T_2} \qquad \text{Equation 26-3-2}$$

Where:

P_1 = original absolute pressure
V_1 = original volume
T_1 = original absolute temperature
P_2 = new absolute pressure
V_2 = new volume
T_2 = new absolute temperature

The significance of gas with respect to hydrostatic testing is the reservoir of energy represented by entrapped gas. When a system is completely filled and pressurized with liquid (no entrapped gas), a system rupture quickly depressurizes the system due to the incompressibility of liquids. However, if the system has reservoirs of entrapped gas, a system rupture results in a "blow down" as the gas pressure diminishes in accordance with the ideal gas law. Accordingly, it is not desirable to have entrapped gases in a component or system during hydrostatic testing.

Effects of Temperature

Temperature affects the density of fluid and therefore the volume of fluid if pressure is held constant. Thermal expansion coefficients, which are determined experimentally, vary from one type of fluid to another and they are not necessarily linear with temperature. Nonetheless, it is true with respect to practical hydrostatic testing that pressure varies in direct proportion to variations in temperature.

In the closed system during hydrostatic testing, small temperature fluctuations give relatively large changes in pressure. This is due to the incompressibility of the fluid. That is, the fluid's attempt to change volume as temperature changes is reflected as pressure changes. The relationship of temperature changes to pressure changes is dependent on volume of the system, working fluid, elasticity of the system and the temperature range. Rather than attempting to establish an exact relationship, practical application of hydrostatic testing demands that temperature be essentially constant. Therefore any heat transfer devices within the system are turned off during hydrostatic testing. Because the water supply is normally somewhat cooler than system ambient, there is a tendency for pressure increases due to thermal expansion of the water. If pressure approaches limits, water is drained from the system to lower pressure.

Basic Concepts

From the foregoing discussion, four basic concepts are derived. These concepts apply to any application of hydrostatic testing:

- filling of the component or system is accompanied by venting of gases

- pressure is raised in the filled component or system by further addition of water at any point.
- temperature of the water is held essentially constant and if thermal expansion causes undue pressure increases, water is drained from the system to counteract the temperature effects.
- leakage at any point is indicated by loss of pressure and by visible evidence of the leaking fluid.

HYDROSTATIC TESTING APPARATUS

Fluid

Hydrostatic testing of nuclear components and systems uses water as the testing medium. Water is plentiful, inexpensive, and compatible with most nuclear components and systems. For components and systems where hydrostatic tests with water cannot be performed, pneumatic pressure tests are substituted as described later in this module.

Apparatus

Hydrostatic testing is relatively simple and little test equipment is required. Each hydrostatic test uses essentially the same types of equipment. As illustrated in the simplified diagram of Figure 26-3-1, there are five types of basic equipment; water supply, hydro-pump, vents and drains, pressure gages, and relief valves.

Water Supply

The quality of the water used for hydrostatic testing is determined by the requirements applicable to the component or system being tested. For components and systems which supply or can supply water to the reactor during plant operations, strict cleanliness conditions are applicable

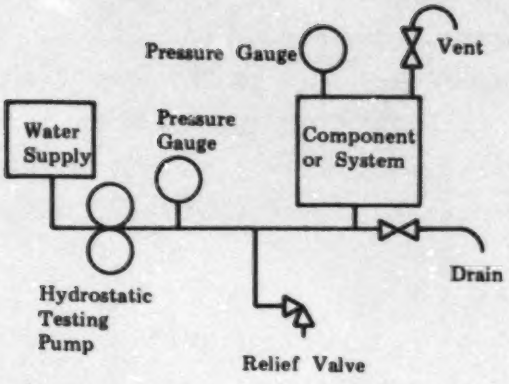


Figure 26-3-1. Simplified Diagram of Hydrostatic Testing System

to avoid the introduction of materials which can become radioactive during reactor operation. For other components and systems, cleanliness requirements are based on maintaining the functionability of the components and systems. Within this framework, engineering specifies one of the following sources of water for hydrostatic testing: (1) demineralized water, (2) potable water, or (3) fire main water.

- demineralized water - Demineralized water is essentially pure in that its conductivity is 3 micromho/cm or less, its pH is about 7.0 and its halogens are less than one part per million. Demineralized water is used for hydrostatically testing reactor systems or for flushing such systems after hydrostatic tests with lesser quality water.

- potable water - Potable water is from the sources of drinking water. It is used in hydrostatically testing all other components and systems unless fire main water is used.
- fire main water - The quality of fire main water varies widely from plant to plant. When it is essentially of potable grade, it is frequently used for hydrostatically testing non-reactor systems.

Hydrostatic Testing Pumps

Pumps used for hydrostatic testing are positive displacement pumps. This class of pump forcefully adds a given quantity of water on each cycle of the pump. Thus, it is capable of increasing discharge pressure to the values necessary for hydrostatic testing.

Hydrostatic testing pumps may be reciprocating, gear, or lobe pumps. The prime mover may be manual, electric, or pneumatic. The pneumatic reciprocating pump has widespread use due to its variable speed and convenient power source. In any event, the specific pump used must have a pressure rating equal to or higher than the maximum hydrostatic test pressure.

Vents and Drains

Vents serve to provide an escape route for atmospheric gases during initial fill of the component or system. To ensure complete removal of gases, vents are installed at each "high point" where gases could otherwise be entrapped. Such vents may be permanently installed or may be installed temporarily for the expressed purpose of supporting the hydro-static test. Temporary vents are removed subsequent to hydrostatic testing. Vent valves are normally manual globe valves rated at or above maximum hydrostatic test pressure.

Drain valves serve to provide an escape route for the water whenever the component or system is drained. These valves are installed permanently or temporarily at the "low points" of the component or system. They are normally manual globe valves and are pressure rated at or above maximum hydrostatic pressure.

Both vents and drains are frequently equipped with hose connections. This permits use of hoses to direct water from vents or drains to satisfactory collection points such as storage tanks or sewers. It avoids permanent piping for this purpose.

Pressure Gages

For hydrostatic testing of new components and systems, at least one direct reading pressure gage is required. If the gage is located out of view of the operator of the hydrostatic test pump, another identical gage is installed on the pump discharge for monitoring by the pump operator. Normally, bourdon tube pressure gages are used.

Each pressure gage has a range of no less than 1½ and no more than 4 times the test pressure. This range provides ample over-pressure range, uses the most linear portion of the range, and offers adequate discrimination of gage increments for readability. Each pressure gage is calibrated with a dead weight tester prior to each use or at two week intervals if it is used continuously.

Relief Valves

Relief valves provide over-pressure protection during hydrostatic testing. Relief valves may be integral with the pump such that pump discharge is returned to pump suction if the relief valve opens. Relief valves may be temporarily installed to the pump discharge or to the component or system

such that pump discharge is directed to a drain if the relief valve opens. In any event, the relief valve must provide a flow rate equal to or greater than pump flow rate at the set point pressure.

Relief valves may be self-actuating or actuated by an external source such as electrical solenoid or pneumatic piston or diaphragm. For externally actuated relief, pressure sensing devices are necessary to actuate the solenoid or pneumatic controls at a predetermined set point.

Installed systems typically have a relief valve as an integral part of the system. However, the set point of such reliefs is normally lower than the maximum hydrostatic test pressure. Reliefs with such lower set points are gagged shut during hydrostatic testing.

APPLICATION

The ASME Boiler and Pressure Vessel Code, (Code) which governs pressure boundary components, requires hydrostatic testing of each component and system which is built or installed to the Code. However, nuts, bolts, studs, and gaskets are not individually tested. Instead, test of the assembled component or installed system tests these parts if they are serving in a pressure retaining capacity. In addition to Code requirements, the designer of "balance-of-plant" systems may stipulate hydrostatic testing of the installed system as one means of determining the acceptability of the system.

When components are destined to be installed into systems which require hydrostatic testing, procurement documents typically require the supplier to hydrostatically test the component prior to its delivery. This ensures that the basic component is capable of passing the test and avoids

the risk of repair costs at the construction site. If hydrostatic testing of a component is delayed until the test of the entire system, failure of the component presents much more difficult repair or replacement conditions and may jeopardize the construction schedule.

At the power plant construction site, installed systems are hydrostatically tested as a portion of the owner's acceptance of the systems for operations. Because such tests of installed systems are more complex than tests of individual components, the remainder of the module deals solely with system hydrostatic tests at the power plant site.

PROCEDURES FOR SYSTEM HYDROSTATIC TESTS

Plant Conditions

As the construction of a nuclear power plant nears completion, a series of preoperational and acceptance testing is instituted by the owner. These tests determine that the plant systems function as intended and that safe and reliable plant operations can commence. One of the first of such tests is the system hydrostatic test.

Few power plant systems are completely divorced from other plant systems. Instead, there are normally interconnections among systems. Interconnected systems may have different design pressure ratings. Also, portions of a given system may have different design pressure ratings than the remainder of the system. For example, a pressure relief system may be rated up to the relief valve at higher pressure than the system it protects while downstream of the relief valves, it may be rated at a pressure lower than the system it protects. Other examples include the water supply portions of system which serve only for initially filling the system.

Because of the interconnections and due to the need for a practical schedule for conducting hydrostatic tests, either portions of a system or a single system are normally tested individually. Nonetheless, if installation is complete, interconnected systems of equal pressure ratings can be hydrostatically tested simultaneously.

Prerequisites

The owner has the responsibility of ensuring that a system is ready for hydrostatic testing. In carrying out this responsibility, the owner prearranges or accomplishes the following prerequisites:

- Compliance with nil-ductility temperature limits - For each pressure retaining system, a permissible lowest service temperature is established by impact testing of the materials used in constructing the system. The permissible lowest service temperature is the minimum temperature at which the system is pressurized. It is a value greater than the nil-ductility transition temperature and it ensures that the material is in its ductile range versus a brittle fracture range. Hydrostatic testing is always performed at a system and water temperature greater than permissible lowest service temperature in order to preclude the possibility of brittle fracture.
- Notification of Authorized Inspector - The ASME Boiler and Pressure Vessel Code requires that hydrostatic tests of systems of pipe size greater than four inches be witnessed by the Code Authorized Inspector. For small systems, the Code Authorized Inspector must review the test report. It is incumbent on the owner to make necessary arrangements with the Authorized Inspector to perform these duties.

- Exposure of welded and mechanical joints - Prior to testing, thermal insulation is not installed or is temporarily removed for welded and mechanical joints. This permits visual inspection of such joints during the hydrostatic test.
- Restraint or isolation of expansion joints - The design of expansion joints may not permit them to carry the pressure loading during hydrostatic testing. In such cases, they are temporarily restrained or isolated until completion of the test.
- Provisions for system isolation - The system or portion of system to be tested must be capable of being isolated from other connecting systems. Installed valves or temporary blank flanges of adequate pressure rating must be available for isolation purposes.
- Addition of temporary supports - When systems which carry vapor or gas in service are hydrostatically tested, the installation design of such systems often cannot support the weight of water. In such cases, additional temporary supports are used until completion of hydrostatic testing.
- Availability of written procedure - Due to the complexity of system hydrostatic testing, written procedures are prepared which give instruction on conducting the test.
- Availability of trained personnel - Personnel who conduct hydrostatic testing must be knowledgeable of the system and of testing techniques. The competence of testing personnel is certified by a company examiner based on the training and experience of each person. This helps to ensure safe conduct of the test with respect to equipment and personnel safety.

- Availability of testing apparatus - In addition to the water supply, pump, pressure gauges, hoses and connections fundamental to any hydrostatic test, the owner ensures that vents and drains exist or are temporarily installed for hook-up of the apparatus to the system. It is also good practice to have surplus fittings, seals, and gauges on hand in the event of the need to replace any of the temporary connections.

Written Procedure

A written procedure is prepared and used for each system hydrostatic test. Each procedure normally contains nine elements as follows:

- Title - The title is descriptive of the system to which the procedure applies. It includes a revision number and date and an approval signature. The title provides for individual identity of each procedure and bears evidence of being a procedure approved for use.
- Applicability - A definitive statement is made on the purpose of the procedure. The statement defines the boundaries of the system which are tested by the procedure.
- References - The source documents which establish requirements being met by the procedure are listed. This permits convenient reference to such documents whenever there is need to review the procedure for compliance with requirements. Also, if the procedural steps require work in accordance with another document or procedure, such other documents and procedures are listed. This permits convenient cross-reference with other documents and procedures.

- Prerequisites - The prerequisites for the specific hydrostatic test described by the procedure are stated. This provides a listing of conditions which are confirmed at the outset of the actual test.
- Precautions - Any precautions applicable to overall conduct of the test are listed. Precautions applicable to specific procedural steps are listed later in the procedure adjacent to the step. Precautions listed at this point are those pertaining to general safety and to possible contingencies. For example, the minimum system and water temperature for the test may be listed.
- Limitations and actions - This element calls for listing limits applicable to the overall test and actions to take if such limits are exceeded. It helps to ensure the overall safe conduct of the test. For example, this element might state "Pressure shall not exceed x lbs/in^2 at any time during the test. In the event pressure reaches x lbs/in^2 at any time, the operator shall immediately stop the test pump and open abc drain valves until pressure is reduced to designated pressure."
- Main Body - Step-by-step instructions are given in sufficient detail for trained personnel to properly conduct the test. Instructions are provided for each person who has tasks to perform. As appropriate, sequence of tasks are delineated and precautions applicable to individual tasks are stated. The main body begins with requiring confirmation of meeting prerequisites, proceeds with conduct of the test, and concludes with restoring the system to a specified condition. In other words, all necessary instructions are given for setting up the system, testing it, and restoring it to a preferred configuration and condition.

- Acceptance criteria - Specific criteria are listed by which the results of the test are deemed acceptable. For welded and mechanical joints, no visible leakage is typical. For valve seats and stems and for pump shafts, a maximum leak rate is typical. In any event, the acceptance criteria serve to provide specific limits for judging the acceptance of the tested system.
- Check off lists - Hydrostatic testing invariably involves positioning valves, making test equipment connections, and possibly adding temporary blanks, fittings and valves. The number of these manipulations makes it more convenient to use check off lists than to detail each manipulation in the procedure's main body. Check off lists are made attachments to the procedure and are made mandatory by steps within the main body of the procedure. Each check off list names specific valves, blanks, connections, and other apparatus such as electrical power switch gear and lists the position in which each item is to be placed. Normally, there are two check off lists: one for lining up the system to permit conduct of the hydrostatic test and one to place the system in the desired condition subsequent to completion of the test. In this manner, better assurance of correct line up is obtained because reliance is not placed on operator's memory of what line up exists.

Specific Techniques

While hydrostatic testing is basically a simple test, there is considerable room for error in preparing for and conducting the test. Most errors tend to be ones which physically limit the ability to pressurize the system and are, therefore, "on the safe side". Even these, however,

slow the conduct of the test and needlessly add costs. The following techniques are based on experience; these should be considered whenever hydrostatic testing is performed:

- System boundary isolation - Any opening in a system prohibits pressurization if the opening is to atmosphere or it leads to unintentional stopped pressurization of another system if the opening is to another system. Such events are avoided if check off lists are complete and correct for system boundaries. A recommended technique for ensuring boundary isolation is the requirement for a review person to mark the desired boundaries of the test on the as-built drawing of the system and then review the check off list for inclusion of each boundary point. In marking the drawing, the person looks for and marks each possible escape route from the system and each connection to the system which is not to be tested by the hydrostatic test. In this manner, all interconnections, vents, drains, instrumentation lines, expansion joints, and any other boundary point are accounted for.
- Tightness of test connections - The connections of the hydrostatic test pump with the system and the connections of temporary vents, gauges, drains, or blanks to the system are potential sources of leakage. Where practicable, these connections are hydrostatically tested prior to testing the system. Where such testing is impracticable, observers are assigned to visually inspect such connections for leakage as pressure is being applied. These techniques provide for early detection of leaking connections which permit more timely correction. Also, surplus fittings, gaskets, "O" rings, etc., should be on hand for quick replacement of leaking connections which cannot be corrected by tightening the joints.

- Filling and venting - As previously described, vents are placed on system high points to vent the system during filling. To ensure adequate removal of gases, most companies have adopted a technique involving use of clear tubing connected to each vent. Operators are instructed to leave the vent open until a full stream of water without air bubbles flows through the tubing.
- Pressure gauge connections - Most instances of system overpressurization have occurred due to isolated or partially isolated pressure gauges. That is, a valve in the gauge sensing line is unintentionally left closed or partially closed. To avoid this problem, companies either require two independent checks that gauge sensing line valves are open or require installation of the gauge without valves in the sensing line. Also, it is good practice to keep the operator of the test pump advised of the closing of system vents. When the last vent is closed, the pump operator expects to see an increasing pressure indicated by the gauge, otherwise, some problem is suspected and reported.
- Tag out system - As described previously, systems are lined up for hydrostatic testing in accordance with check off lists. To guard against someone else altering the lineup for some other test or work activity, an administrative tag out system is used. Each valve, switch, breaker, and other device whose position must not be changed during the hydrostatic test is tagged. Typically, the tags used are red in color and contain the caution of "Danger-do not operate". Each tag is serialized and listed in a logbook at the time of placing tags on items. At the end of the test, each tag is checked off in the logbook as they are removed. This type of system

protects personnel and equipment from the consequences of unauthorized operation of valves, switches, breakers, etc.

- Removal of temporary items - As previously described, the conditions of a system at the time of hydrostatic testing sometimes require installation of temporary devices such as supports, valves, blanks, etc. At the conclusion of the test, these temporary devices must be removed. To ensure removal of each temporary device, one of two techniques is common. First, a check off list for temporary devices can be made part of the procedure. Secondly, a logbook can be used to record installation of each temporary device and subsequent removal.

INSPECTION

General

For each hydrostatic test, one person is designated as the lead tester who is responsible for all inspections and signing of the test report. Other testing personnel report to the lead tester on conduct of each step of the procedure including the performance of inspections.

Inspections associated with hydrostatic testing are concerned with test pressure, time at pressure, and leaks.

Test Pressure

System design specifications establish system design pressure in accordance with the ASME Boiler and Pressure Vessel Code or other design criteria. These specifications stipulate hydrostatic test pressures directly or by reference to the applicable design criteria. The hydrostatic testing procedure implements the stipulated test pressure. The lead

tester is responsible for determining that the test is performed at the stipulated test pressure. In general, the systems are tested at 1.25 times the system design pressure.

Time at Pressure

The ASME Boiler and Pressure Vessel Code requires that test pressure be held for a minimum of ten minutes prior to inspection for leaks. This time provides for ample opportunity for water to seep through small leaks which may be present and thereby be visible upon inspection. The lead tester is responsible for ensuring compliance with this requirement.

Inspection for Leaks

For most system hydrostatic tests, some leakage is expected through valve seats, valve stems, and pump shafts. For this reason, inspection for leaks by pressure loss is not feasible, Instead, the system is visually examined for leakage. In general, the following criteria apply:

- no visible leaks at welded and mechanical joints.
- no visible leaks at transitions and areas of high stress.
- no visible leaks around stems and shafts where the design does not permit leakage.
- compliance with designated leak rates around stems and shafts where the design permits a specified amount of leakage.

In performing the visual inspection for leaks, visual aids may be used. For example, blotter paper may be used to determine if joints are leaking. Portable lights are normally needed for adequate visibility.

When leakage around stems and shaft seals is expected due to the design, provisions are necessary to prevent such

leakage from masking other possible leakage. In some cases, permanent leakage collection systems are installed. For other instances, an acceptable technique is the temporary placement of a coffer dam around the stem or shaft and tubing for draining the leakage away from the system. When it is required to measure the leak rate from stems or shafts, this arrangement provides for easy measurement.

When required, leak rate measurements around stems and shafts and across valve seats are made by the timed collection of leakage. Permanent leakage collection systems or temporary tubing on the unpressurized side of these items permits collection of leakage in graduated containers for a timed interval. Leak rate is determined by dividing the quantity collected by the time of collection. For example, collection of 15 milliliters of water in a ten minute interval computes to a 90 mililiters per hour leak rate.

ALTERNATIVES TO HYDROSTATIC TESTING

If it is not practical to perform a hydrostatic test, a pneumatic test is performed. Pneumatic tests are performed when, (1) the system design strength does not permit safe filling with water, and (2) the system is not easily dried and traces of the test medium (water) cannot be tolerated in service.

Pneumatic testing uses nonflammable gas as the test medium. At nuclear power plants, the gas is normally compressed air although nitrogen or helium may be used. As with hydrostatic tests, the system temperature must be above permissible lowest service temperature.

Conduct of pneumatic testing is identical to hydrostatic testing except for pressure application and inspection for leakage.

Pressure is gradually increased to not more than one-half of final test pressure. After this point is reached, pressure is increased in steps of one-tenth of test pressure until the required test pressure is achieved. In this manner, added safety precautions are taken in the unlikely event of system rupture.

As with hydrostatic testing, the test pressure is maintained for a minimum of ten minutes prior to commencing inspection. Inspection is performed using a leak test method which is suitable for the test medium. For tests with air or nitrogen, the Bubble Test is normally used. For tests with helium, a helium gas leak detector with sniffer probe is normally used. In general helium is used only where leak rate must be measured.

HYDROSTATIC TESTING FOR IN-SERVICE INSPECTIONS

Pressure retaining components within each system boundary are periodically subjected to pressure tests throughout their operational life. ASME Boiler and Pressure Vessel Code, Section XI, establishes test intervals, types of tests, and acceptance criteria for these "inservice inspections". These tests determine the continued integrity of pressure retaining systems throughout the approximately 40 years of plant operation.

Basically, two types of tests are conducted at specified intervals. The second type is visual examination for leakage with the system pressurized above normal operating pressure. The exact test pressure for the second type is specified by the Code for each system classification.

The inservice pressure tests used much of the techniques previously described for hydrostatically testing new systems. However, necessary modifications are made as follows:

- time at pressure - When items hydrostatically tested are not directly accessible for visual inspection due to space restrictions or thermal insulation, test pressure is held for four hours prior to starting the inspection. This permits ample time for evidence of leakage to be present in surrounding areas, e.g., floors, or to be evident on the outside surfaces of thermal insulation.
- inspection - Thermal insulation need not be removed. Instead, the visible surfaces, normally exposed areas, and the surrounding area are visually examined.

As with testing of new systems, any item exhibiting leakage in excess of specific values is repaired or replaced. Written procedures are prepared and approved for executing repair or replacement.

EXERCISES

The following exercises reinforce the objectives of this module. Answer each of the following questions as indicated.

1. Review a hydrostatic test procedure and conduct the hydrostatic test outlined in the Procedures Section of this module. Note, a tour of a test facility is also suggested.

2. Vents are placed at each high point and left open during filling until a stream of water without air bubbles exits the vent. Entrapped gas is undesirable. Why?
3. Changes of temperature of the test medium during hydrostatic testing cause drastic pressure changes. In practice, this effect has most significance to the individual charged with maintaining test pressure. This individual must be alert for excessive pressure caused by temperature increases. Briefly discuss why.
4. Hydrostatic testing apparatus consists of water supply, test pump, pressure gages, vents, drains, and relief valves. Name the purpose of each.
5. Plant conditions require correct determination of boundary points for a given hydrostatic test. Relate the use of check off lists and marked up drawings for ensuring isolation at each boundary point.
6. Hydrostatic testing is performed with system and water temperature above permissible lowest service temperature. Why?
7. The Authorized Inspector is notified of the hydrostatic testing schedule to permit the inspector to witness the tests. Explain the inspectors duties.
8. For initial system hydrostatic tests, welded and mechanical joints must be exposed to permit direct visual examination for leakage. Why is NDE performed?
9. Expansion joints are temporarily restrained or isolated when their design does not permit application of the stresses associated with hydrostatic testing. Briefly discuss why this is done.
10. Temporary supports are added to systems which cannot support the weight of water during hydrostatic testing. Briefly discuss the importance of adding these supports.

11. A written procedure is available for each hydrostatic test. Briefly list the main items in the procedure.
12. The necessary number of vents must be in place prior to filling the system for hydrostatic testing. Why?
13. Written hydrostatic testing procedures normally contain nine elements: title, applicability, references, prerequisites, precautions, limitations and actions, main body, acceptance criteria, and check off lists. Name the purpose of each element.
14. The tag out system places tags on each item which must not be repositioned during the hydrostatic test. In this manner, undesirable operation of the item is avoided. List some precautions which should be used.
15. Removal of temporary items after completion of the hydrostatic test is ensured by either check off lists in the procedure or by use of logbooks. Explain why.
16. Inspection determines use of correct test pressure, correct time at pressure, and acceptability of any leakage. Briefly discuss the importance of these.
17. Leak rate is determined by collecting for a timed interval the leakage occurring within the interval. How?
18. Pneumatic pressure tests are substituted for hydrostatic tests for systems requiring pressure testing but which cannot be filled with water. Either system design strength or incompatibility of water with service requirements are causes for substituting pneumatic pressure tests. Explain why.
19. Pneumatic pressure tests use nonflammable gases such as air, nitrogen and helium. Bubble tests detect leaks when air or nitrogen is used as the test medium. Helium gas leak detectors are used when helium is the test medium. Explain why these now flammable gases are used during pneumatic and bubble tests.

20. Pressure is raised in increments during pneumatic testing as an added safety precaution. Describe the increments used during this pneumatic testing.
21. Inservice pressure tests are conducted at normal system operating pressure. Explain how.
22. Inservice hydrostatic tests are conducted at pressures above normal operating pressure as specified by the ASME Boiler and Pressure Vessel Code. Time at pressure is four hours if joints are inaccessible for direct visual examination. Why?
23. Inservice tests serve to confirm the continued integrity of pressure retaining systems. Visual inspection determines if leakage is occurring. Explain when repair or replacement of the item containing the leak is required.

MATERIALS

The following materials are required to support this module:

1. Hydrostatic test procedures and corresponding component or system drawing (see Procedure #1)
1. Equipment for the conduct of a hydrostatic test (see Procedure #2):
   a. pressure gage
   b. test fittings and tubing
   c. vent and drain valve
   d. relief valve (optional)
   e. water supply
   f. test pump
   g. component to be tested

PROCEDURES

1. Review a Hydrostatic Test Procedure

   a. Materials

      (1) copy of hydrostatic test procedure for each student/trainee or groups of four or less students/trainees. (Hydrostatic test procedures may be obtained from nearby industries or testing laboratories. Or if Procedure #2 is used, students/trainees could be requested to prepare a hydrostatic test procedure).

      (2) Drawing of the system or component represented by the hydrostatic test procedure.

   b. Instructions

      Review the hydrostatic test procedure against the contents of this module and answer the following questions:

      (1) How does the format agree with the nine procedural elements described by this module? List specific differences and describe your assessment of the significance of each difference.

      (2) Mark the boundary points on the drawing and compare them with the procedure. In each boundary point isolated by the procedure.

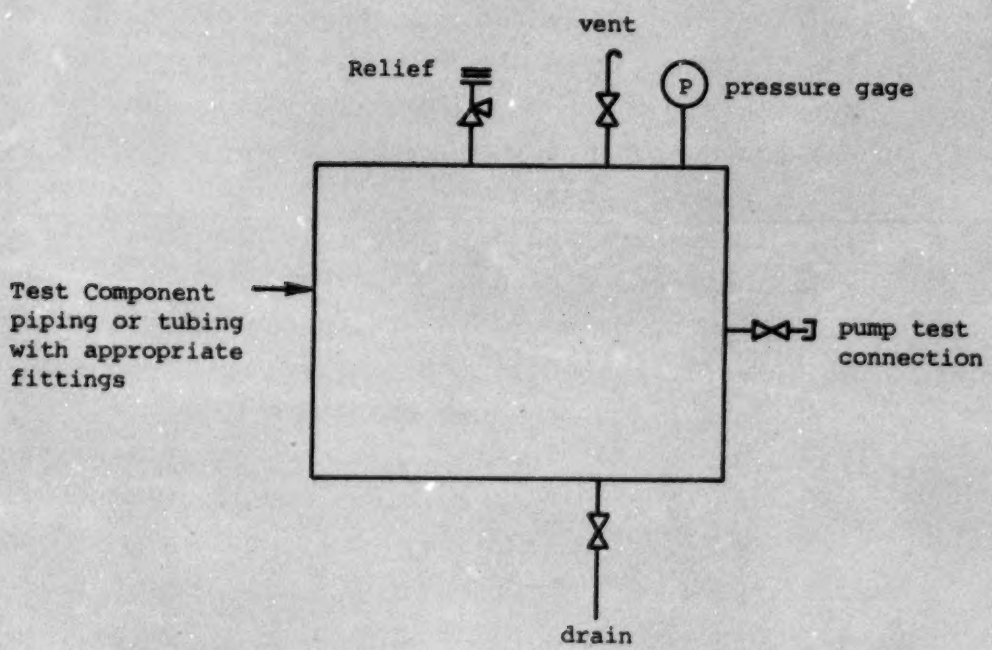
      (3) Compare the procedure with the prerequisites described by this module. Are the stated prerequisites sufficient? What would you add and why?

      (4) Visualize accomplishments of the main body of the procedure. Are there any omissions? What are they and why should they be included?

2. Conduct a Hydrostatic Test

a. Materials

(1) pressure gage
(2) test fittings and tubing
(3) drain valve
(4) relief valve (optional)
(5) water supply
(6) test pump
(7) component to be tested (a test component can be fabricated as illustrated in the following sketch).



b. Instructions

(1) Obtain from the instructor the pressure rating of the component to be tested.

(2) Prepare a hydrostatic test procedure to test the component at 1.25 times the pressure rating using the testing equipment supplied by the instructor.

(3) Obtain review of the procedure by another student/trainee.

(4) Conduct a hydrostatic test of the component using the procedure prepared in step 2.

3. Tour a Test Facility

a. Prerequisites

Completion of arrangements with a testing facility for a guided tour to observe the conduct of hydrostatic testing.

b. Objectives

Observe hydrostatic testing from initial filling through completion of inspection for leakage for the purpose of identifying the technique used.

c. Materials

Writing materials for note taking.

d. Instruction to Student/Trainee

(1) Prepare notes on the techniques used for:
- boundary isolation
- pressurizing to test pressure
- time of pressurization
- examination for leakage

(2) Subsequently, compare your notes with the contents of this module. Make a listing of techniques used by the test facility which you

consider were (a) exceptionally good and (b) somewhat poor. For each technique listed, state your reasons for classifying the technique as good or poor.

REFERENCE MATERIALS

ASME, Boiler and Pressure Vessel Code, Section III and XI, 1979, American Society of Mechanical Engineers

ANSI, Administrative Controls and Quality Assurance for the Operational Phase of Nuclear Power Plants, ANSI N18.7, American National Standards Institute

ANSI, Supplementary Quality Assurance Requirements for Installation, Inspection, and Testing of Mechanical Equipment and Systems for the Construction Phase of Nuclear Power Plants, ANSI N45.2.8, American National Standard Institute

TEST

1. State the fundamental principles upon which hydrostatic testing is based.

2. State Pascal's law.

3. Describe potential consequences of failure to vent all gases should a rupture occur during hydrostatic testing.

4. Describe the effect on pressure of a rupture during hydrostatic testing of a system which has no entrapped gases.

5. Describe the effects of temperature on hydrostatic testing.

6. Draw a simplified diagram of a hydrostatic testing system and label and state the purpose of each item of test equipment.

7. Describe the role of the following prerequisites for hydrostatic testing:
   a. Nil-ductility temperature limits

   b. Authorized Inspector

   c. Exposure of joints

8. Describe the role of the following elements of a hydrostatic test procedure:
   a. Prerequisites

   b. Main Body

   c. Check off lists

9. Describe a technique for performing the following functions in connection with hydrostatic testing:
   a. System boundary isolation

   b. Filling and venting

   c. Tag out

10. Name three inspection attributes for hydrostatic testing and state the purpose of each.
   a.

   b.

   c.

11. Describe a pneumatic pressure test with respect to:
    a. When it is used

    b. Types of gases used

    c. Application of pressure

    d. Inspection for leaks

12. State the purpose of inservice pressure tests during the operations phase of the nuclear power plant.

13. Inservice pressure test is being conducted of a system which is covered with thermal insulation. How long must test pressure be applied and how would inspection be performed?